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(54) **SYSTEMS AND METHODS FOR NON-CONTACT BIOMETRIC SENSING**

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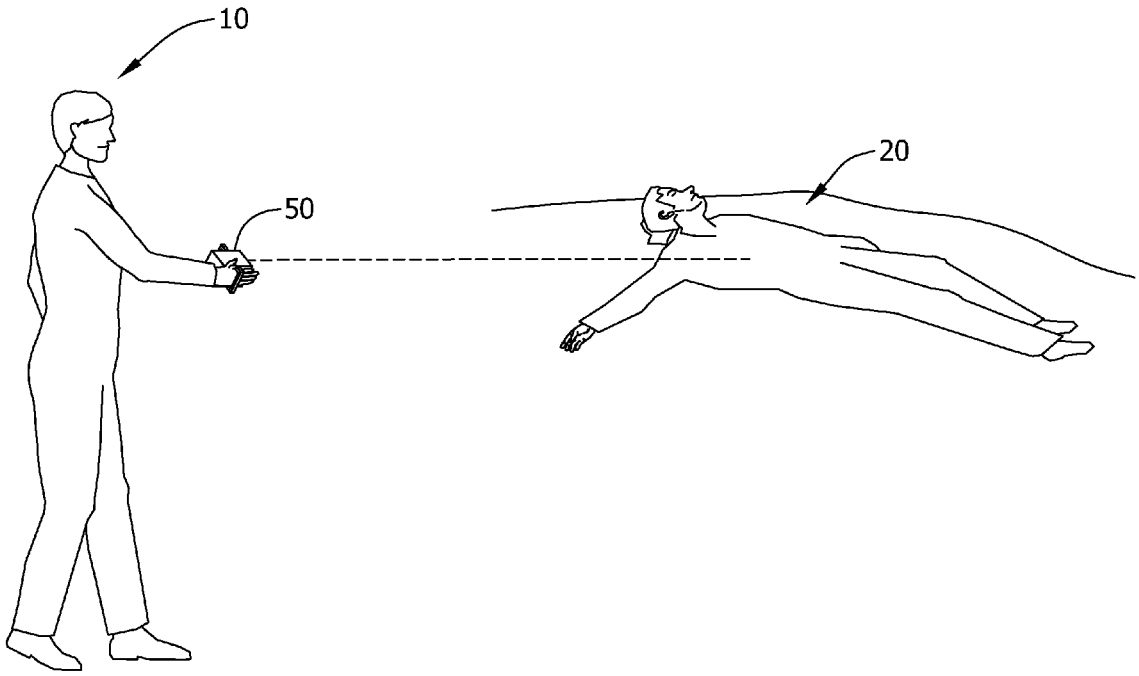
(57) **ABSTRACT**

A non-contact biometric sensing device is described. The device includes a processing device, a user interface communicatively coupled to the processing device, a display communicatively coupled to the processing device, a laser doppler vibrometer sensor communicatively coupled to the processing device, and an infrared camera communicatively coupled to the processing device. The processing device is programmed to utilize mechanical motion data received from the laser doppler vibrometer sensor and thermal distributions data from the infrared camera to calculate biometric data, when signals originating from the laser doppler vibrometer sensor and the infrared camera are reflected back towards the device from a target.



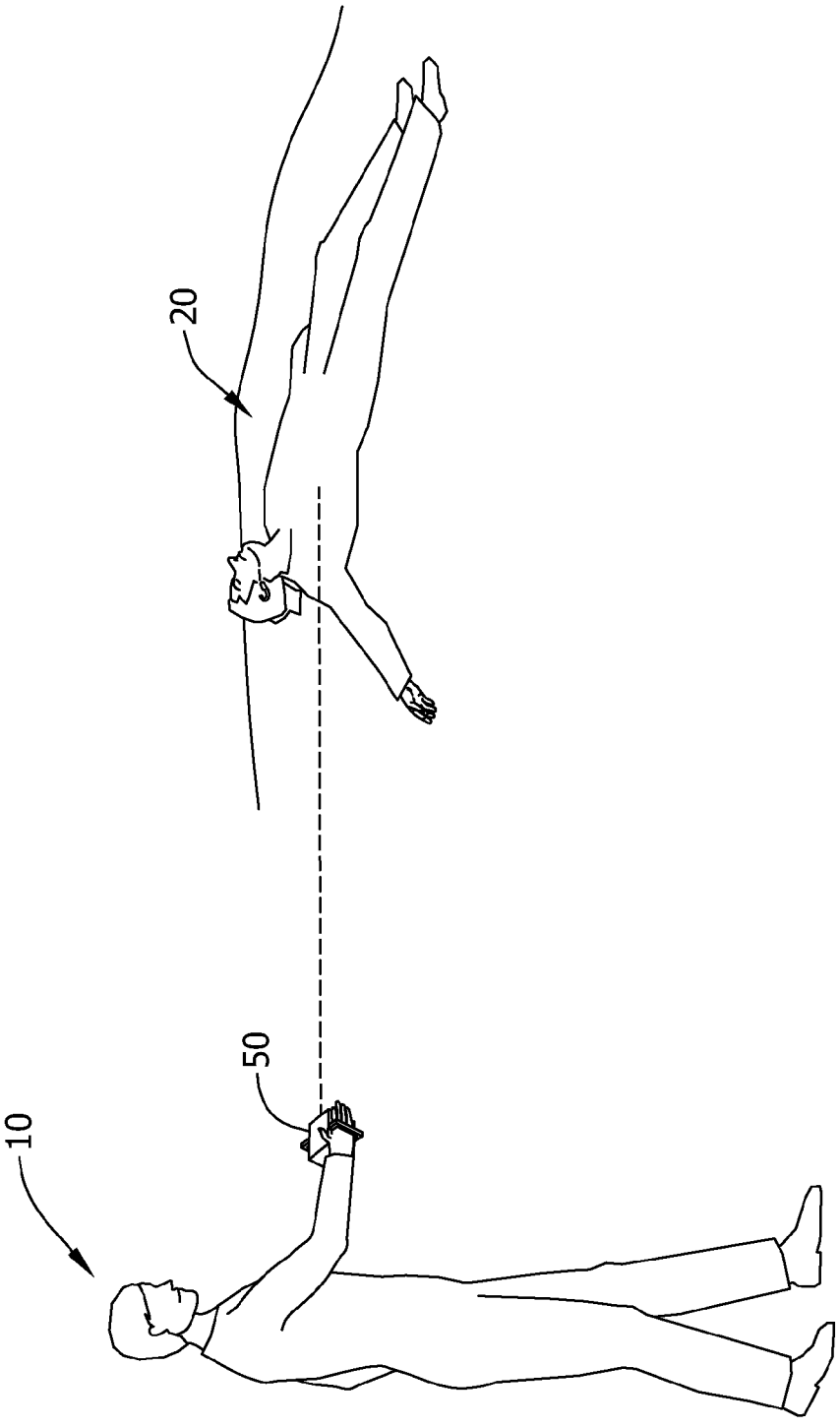


FIG. 1

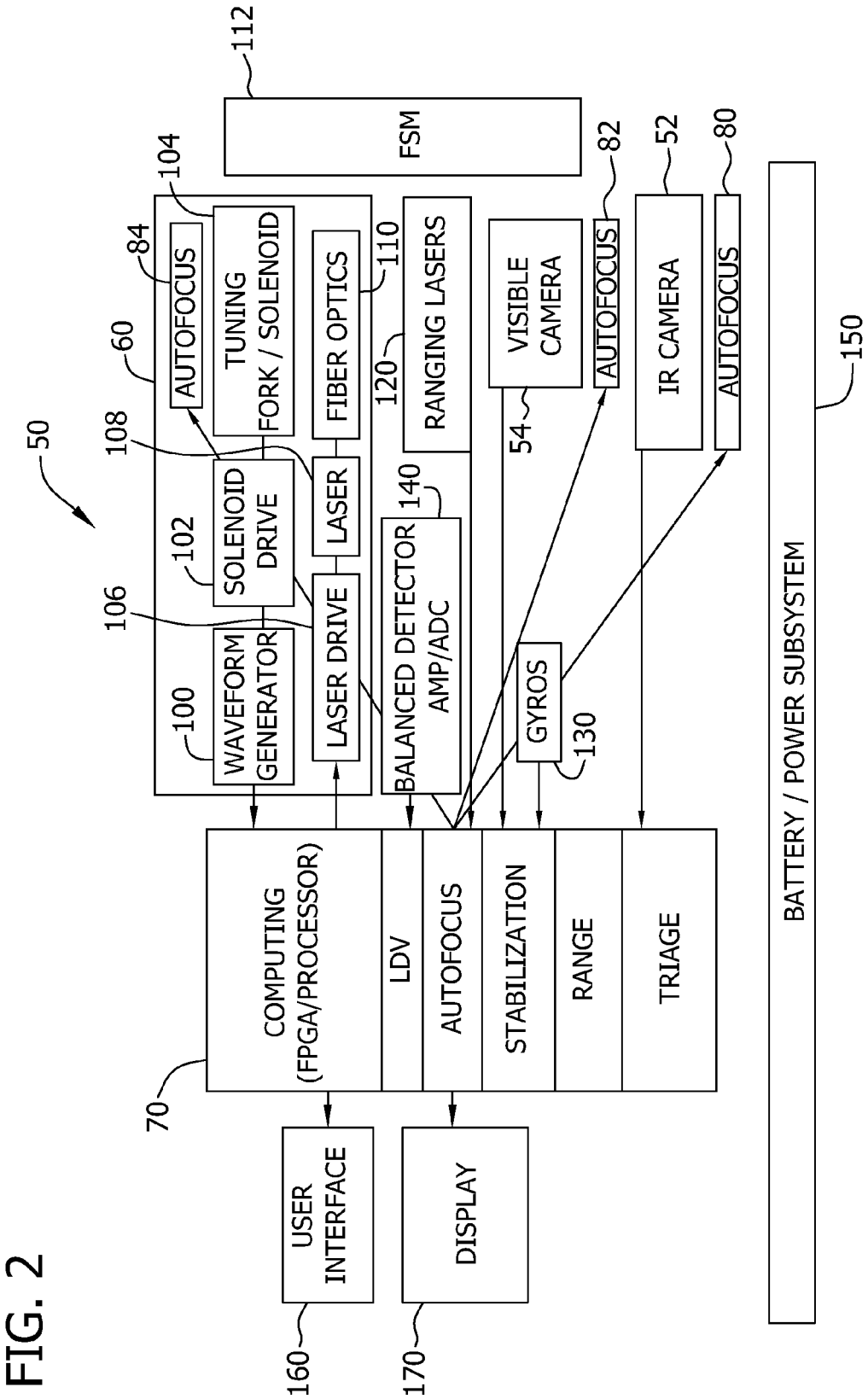

50
112
FSM
104
84
AUTOFOCUS
TUNING FORK / SOLENOID
110
FIBER OPTICS
120
RANGING LASERS
VISIBLE CAMERA
82
AUTOFOCUS
52
IR CAMERA
80
AUTOFOCUS
60
108
102
SOLENOID DRIVE
LASER
140
BALANCED DETECTOR AMP/ADC
54
106
100
WAVEFORM GENERATOR
LASER DRIVE
GYROS
130
150
BATTERY / POWER SUBSYSTEM
70
COMPUTING (FPGA/PROCESSOR)
LDV
AUTOFOCUS
STABILIZATION
RANGE
TRIAGE
160
USER INTERFACE
170
DISPLAY

FIG. 2

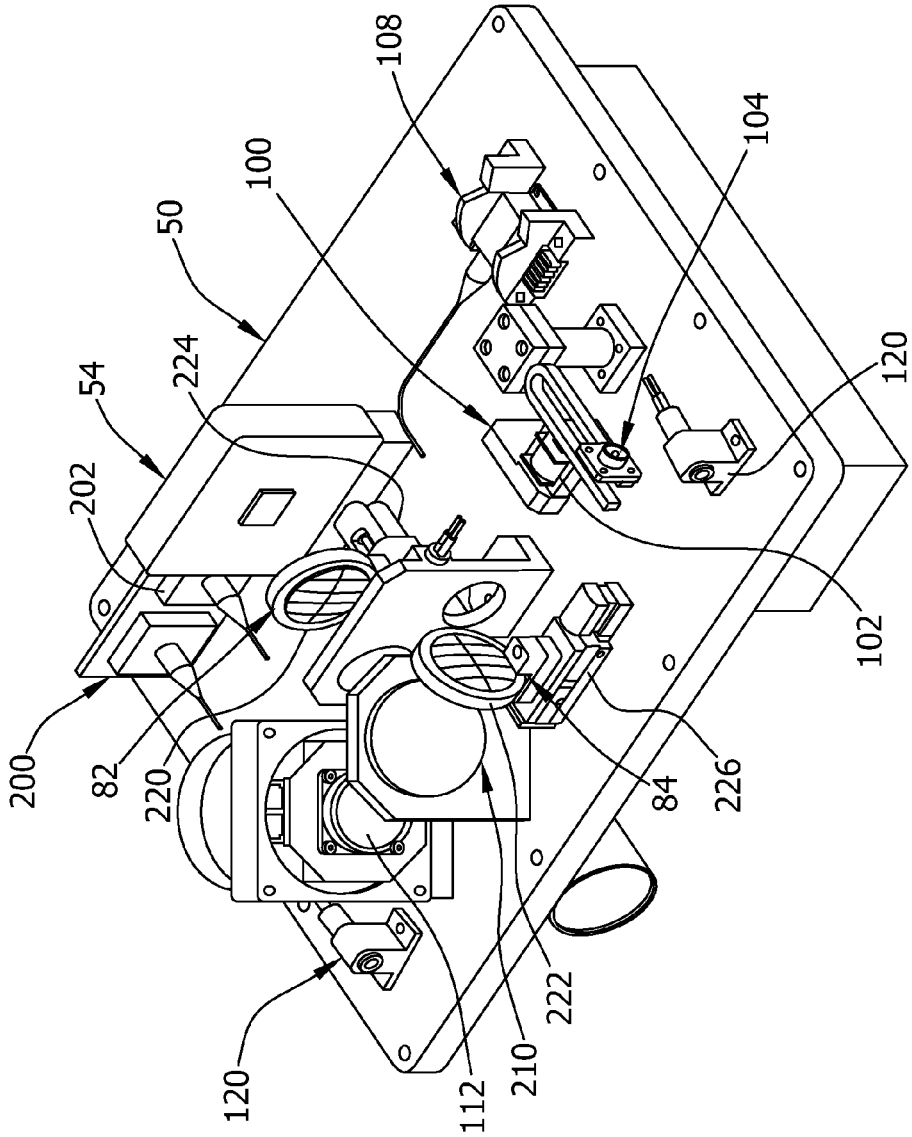

108
104
100
50
120
54
224
202
102
200
82
220
84
226
222
210
112
120

FIG. 3

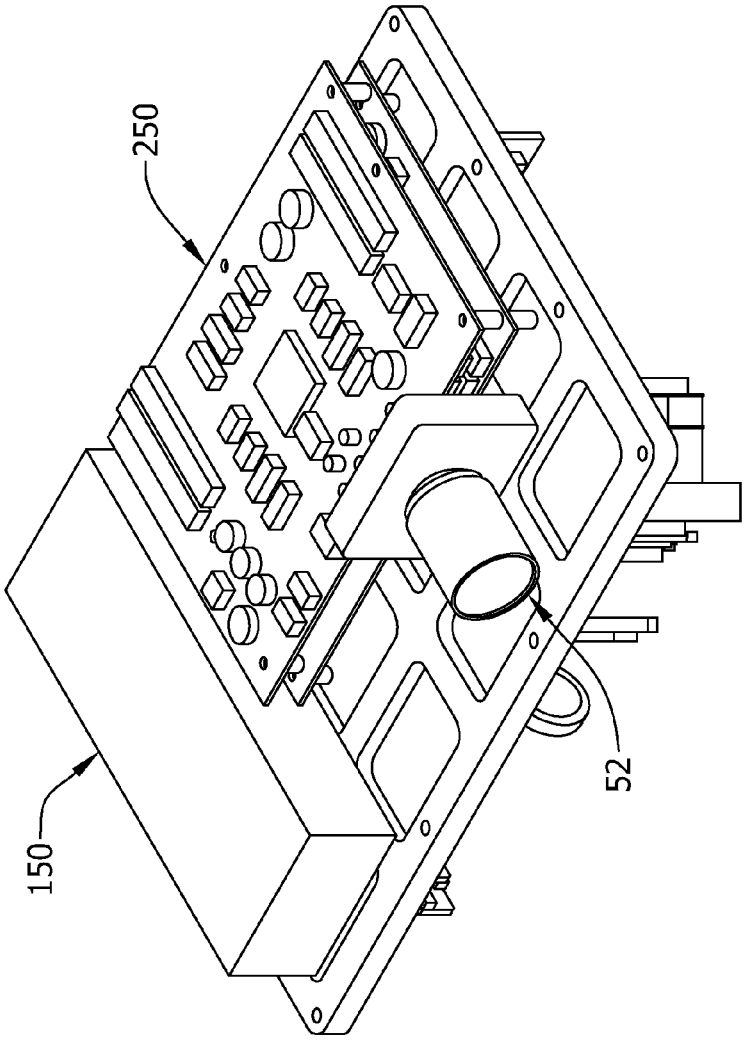


FIG. 4

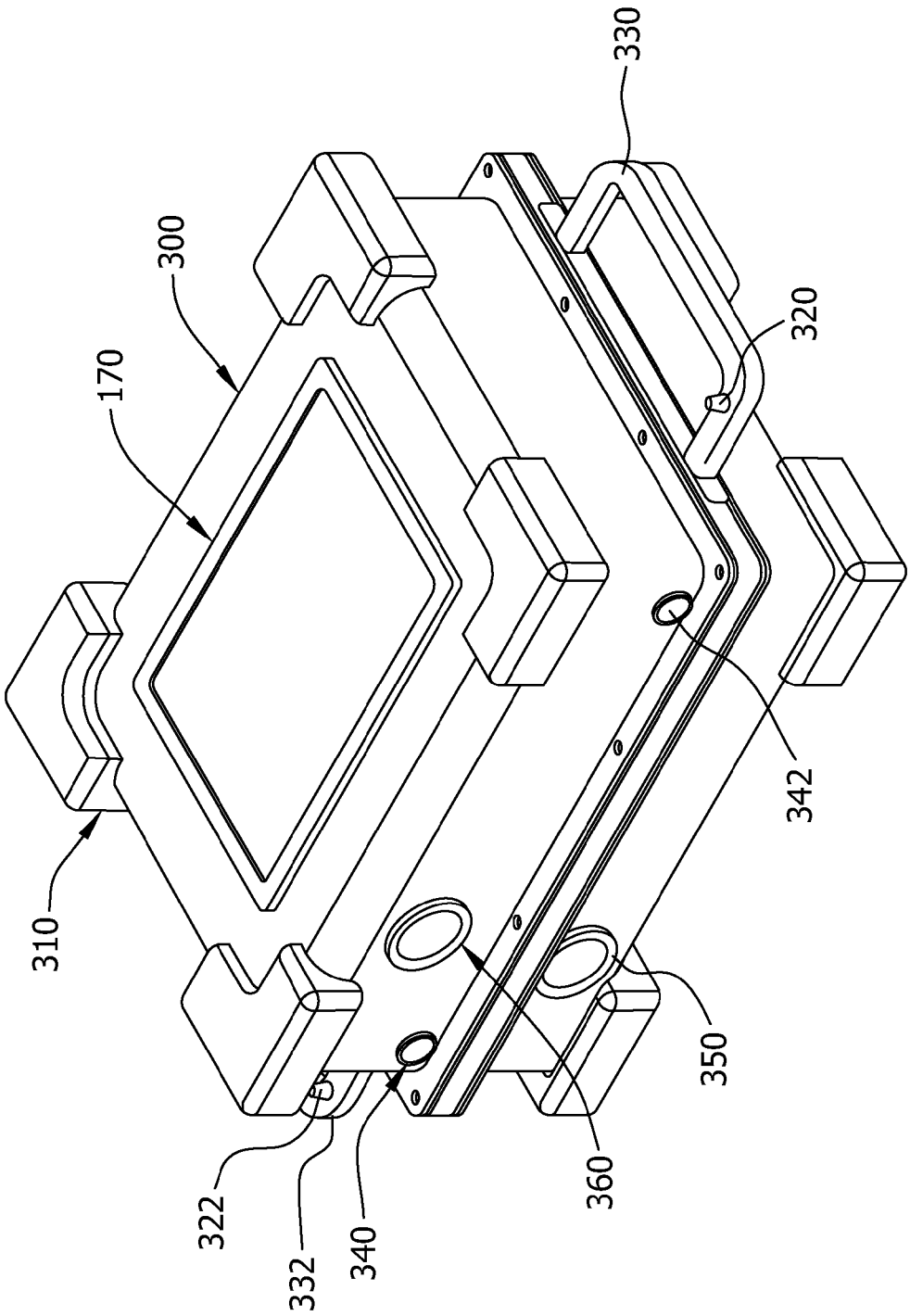


FIG. 5

FIG. 6

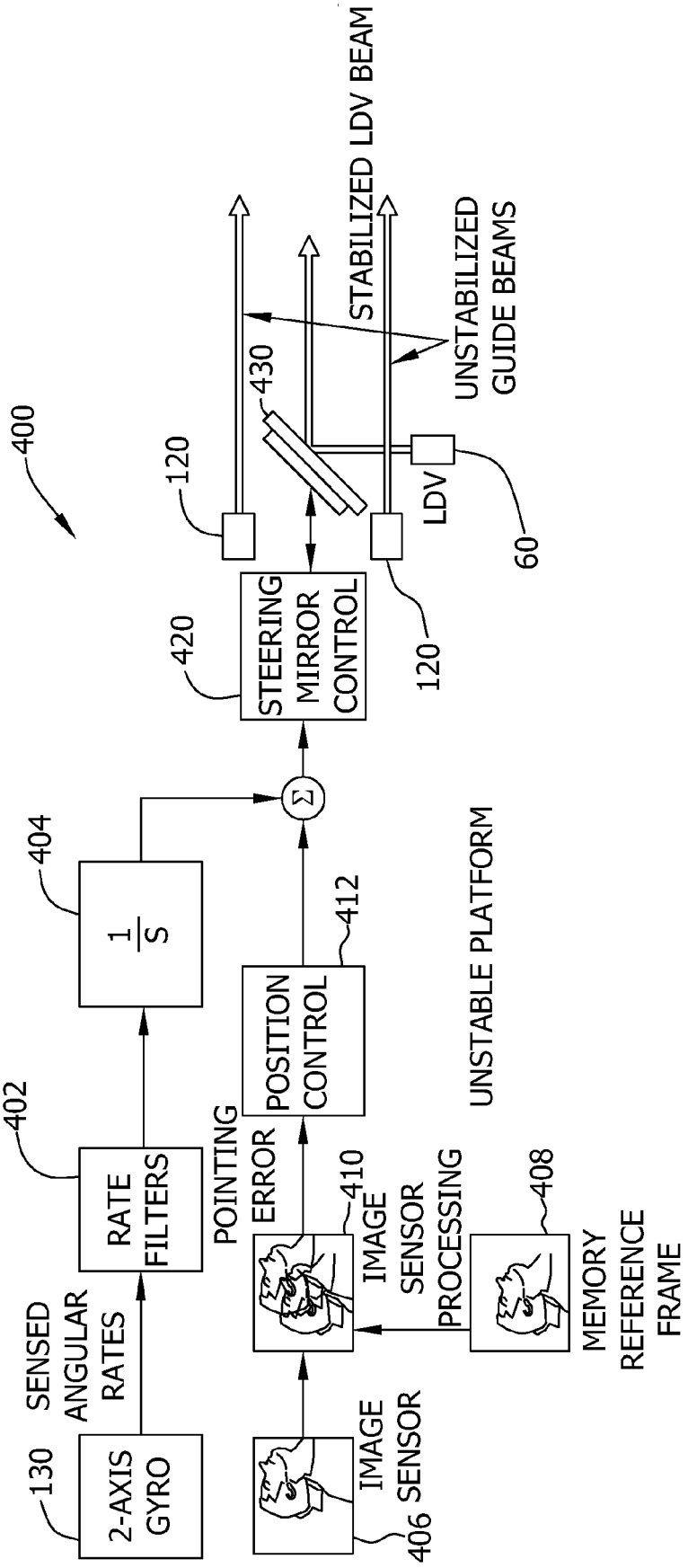

400
130
2-AXIS GYRO
SENSED ANGULAR RATES
402
RATE FILTERS
404
1/S
406
IMAGE SENSOR
POINTING ERROR
410
IMAGE SENSOR PROCESSING
408
MEMORY REFERENCE FRAME
412
POSITION CONTROL
Σ
420
STEERING MIRROR CONTROL
120
120
430
LDV
60
STABILIZED LDV BEAM
UNSTABILIZED GUIDE BEAMS
UNSTABLE PLATFORM

FIG. 7

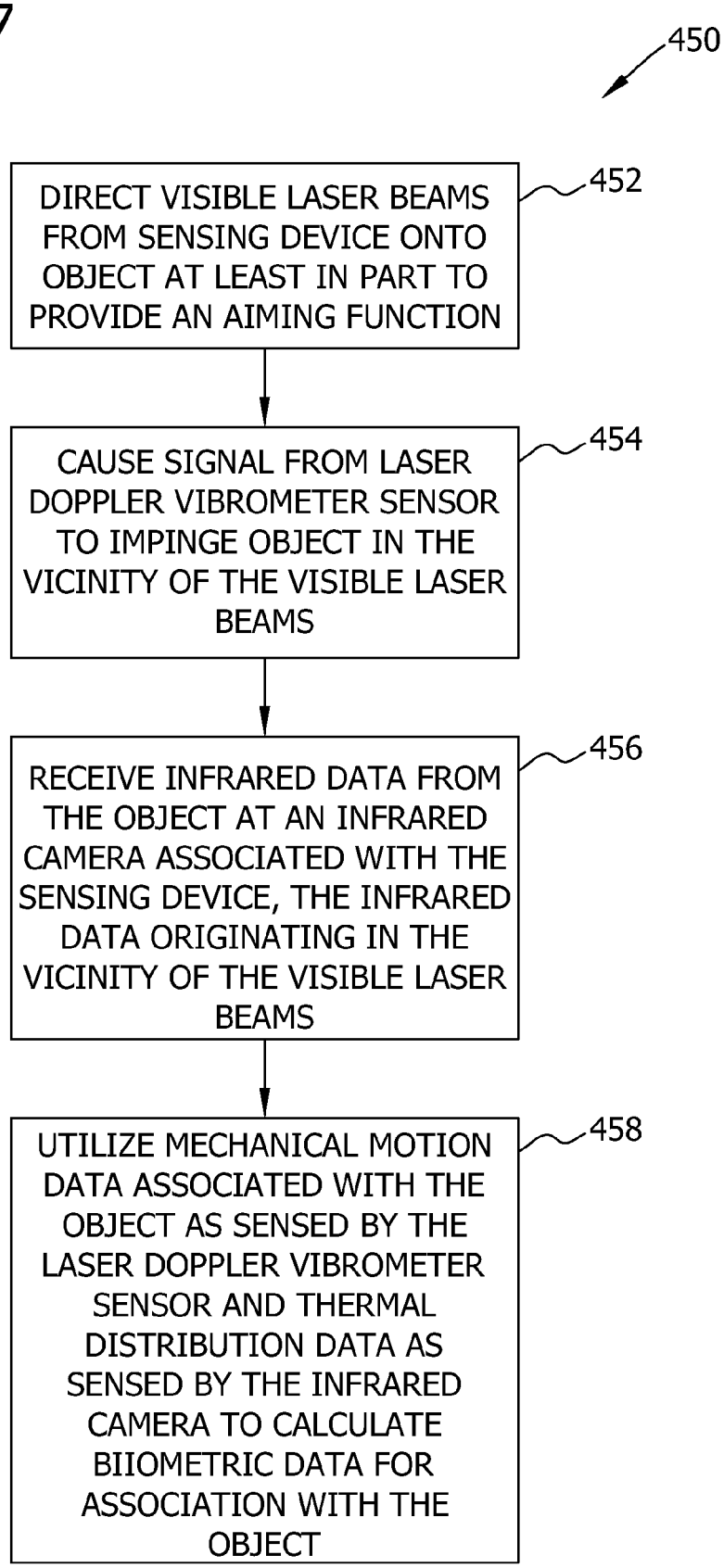

450
DIRECT VISIBLE LASER BEAMS FROM SENSING DEVICE ONTO OBJECT AT LEAST IN PART TO PROVIDE AN AIMING FUNCTION
452
CAUSE SIGNAL FROM LASER DOPPLER VIBROMETER SENSOR TO IMPINGE OBJECT IN THE VICINITY OF THE VISIBLE LASER BEAMS
454
RECEIVE INFRARED DATA FROM THE OBJECT AT AN INFRARED CAMERA ASSOCIATED WITH THE SENSING DEVICE, THE INFRARED DATA ORIGINATING IN THE VICINITY OF THE VISIBLE LASER BEAMS
456
UTILIZE MECHANICAL MOTION DATA ASSOCIATED WITH THE OBJECT AS SENSED BY THE LASER DOPPLER VIBROMETER SENSOR AND THERMAL DISTRIBUTION DATA AS SENSED BY THE INFRARED CAMERA TO CALCULATE BIIOMETRIC DATA FOR ASSOCIATION WITH THE OBJECT
458

FIG. 8

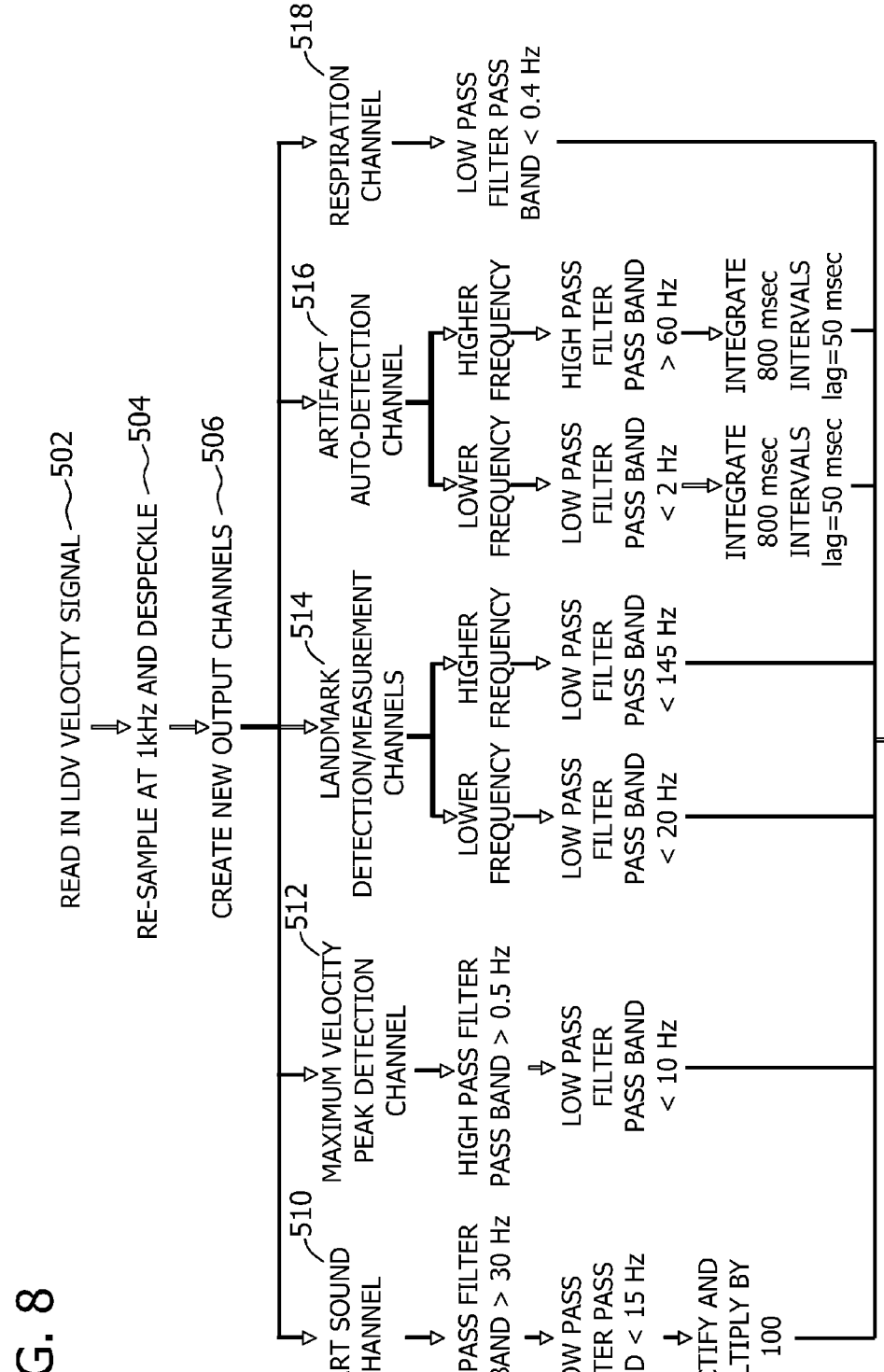

READ IN LDV VELOCITY SIGNAL
502
RE-SAMPLE AT 1kHz AND DESPECKLE
504
CREATE NEW OUTPUT CHANNELS
506
HEART SOUND CHANNEL
510
HIGH PASS FILTER PASS BAND > 30 Hz
LOW PASS FILTER PASS BAND < 15 Hz
RECTIFY AND MULTIPLY BY 100
MAXIMUM VELOCITY PEAK DETECTION CHANNEL
512
HIGH PASS FILTER PASS BAND > 0.5 Hz
LOW PASS FILTER PASS BAND < 10 Hz
LANDMARK DETECTION/MEASUREMENT CHANNELS
514
LOWER FREQUENCY
HIGHER FREQUENCY
LOW PASS FILTER PASS BAND < 20 Hz
LOW PASS FILTER PASS BAND < 145 Hz
ARTIFACT AUTO-DETECTION CHANNEL
516
LOWER FREQUENCY
HIGHER FREQUENCY
LOW PASS FILTER PASS BAND < 2 Hz
HIGH PASS FILTER PASS BAND > 60 Hz
INTEGRATE 800 msec INTERVALS lag=50 msec
INTEGRATE 800 msec INTERVALS lag=50 msec
RESPIRATION CHANNEL
518
LOW PASS FILTER PASS BAND < 0.4 Hz
WRITE RE-SAMPLED, DESPECKLED AND FILTERED CHANNELS TO FILE
520

FIG. 9

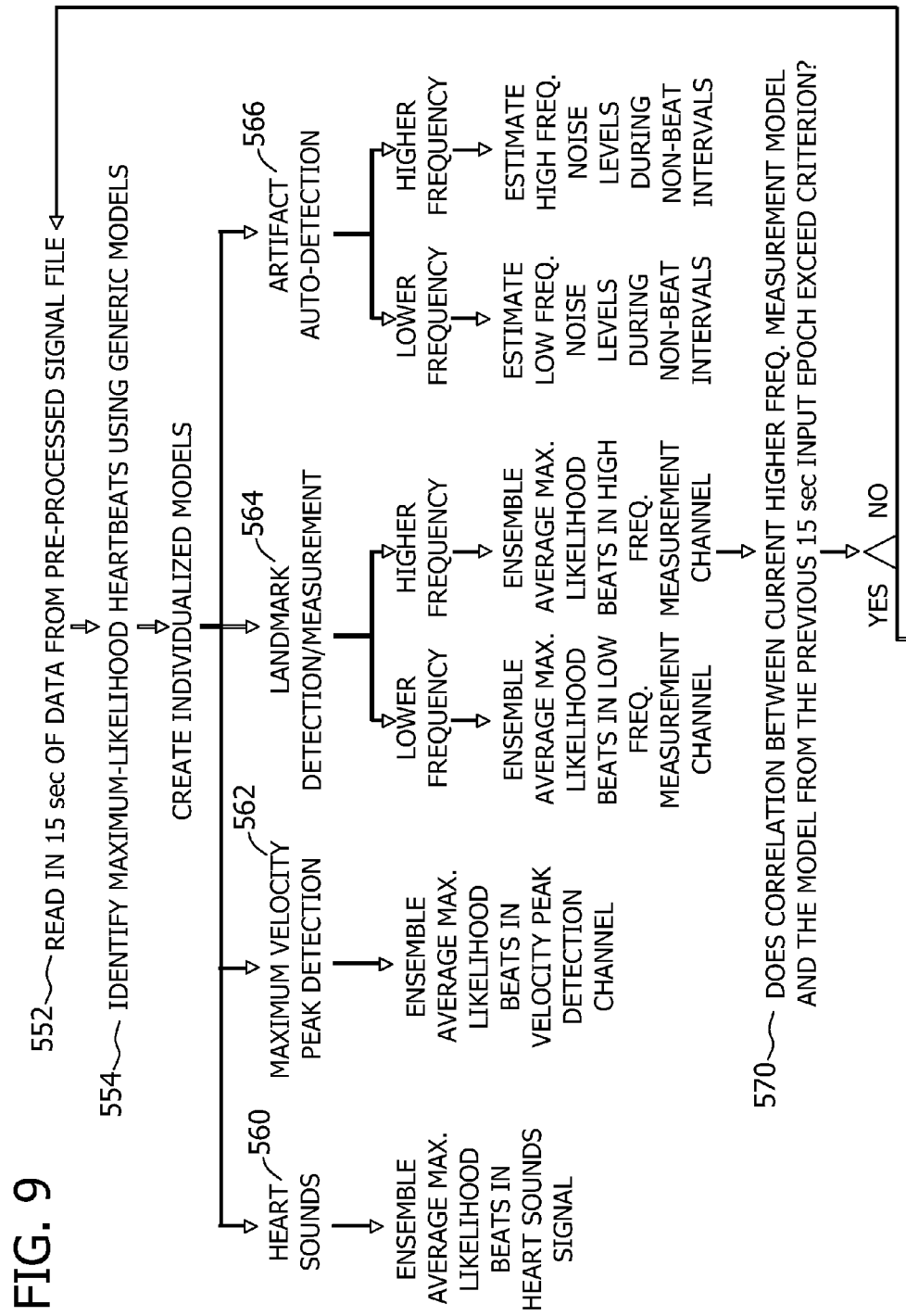

552
READ IN 15 sec OF DATA FROM PRE-PROCESSED SIGNAL FILE
554
IDENTIFY MAXIMUM-LIKELIHOOD HEARTBEATS USING GENERIC MODELS
CREATE INDIVIDUALIZED MODELS
560
HEART SOUNDS
ENSEMBLE AVERAGE MAX. LIKELIHOOD BEATS IN HEART SOUNDS SIGNAL
562
MAXIMUM VELOCITY PEAK DETECTION
ENSEMBLE AVERAGE MAX. LIKELIHOOD BEATS IN VELOCITY PEAK DETECTION CHANNEL
564
LANDMARK DETECTION/MEASUREMENT
LOWER FREQUENCY
ENSEMBLE AVERAGE MAX. LIKELIHOOD BEATS IN LOW FREQ. MEASUREMENT CHANNEL
HIGHER FREQUENCY
ENSEMBLE AVERAGE MAX. LIKELIHOOD BEATS IN HIGH FREQ. MEASUREMENT CHANNEL
566
ARTIFACT AUTO-DETECTION
LOWER FREQUENCY
ESTIMATE LOW FREQ. NOISE LEVELS DURING NON-BEAT INTERVALS
HIGHER FREQUENCY
ESTIMATE HIGH FREQ. NOISE LEVELS DURING NON-BEAT INTERVALS
570
DOES CORRELATION BETWEEN CURRENT HIGHER FREQ. MEASUREMENT MODEL AND THE MODEL FROM THE PREVIOUS 15 sec INPUT EPOCH EXCEED CRITERION?
YES
NO
572
AVERAGE CONSECUTIVE MODELS AND STORE

FIG. 10

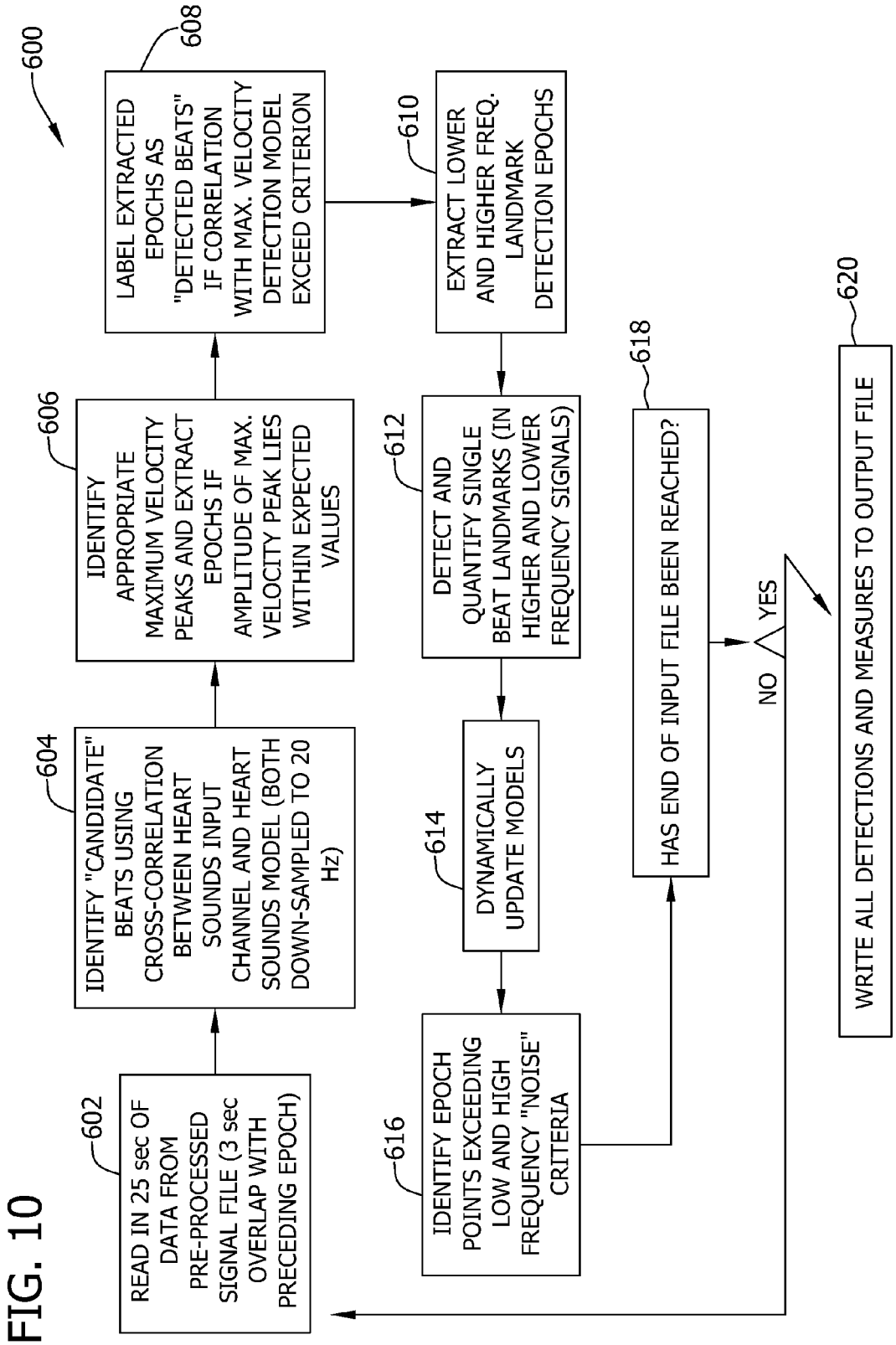
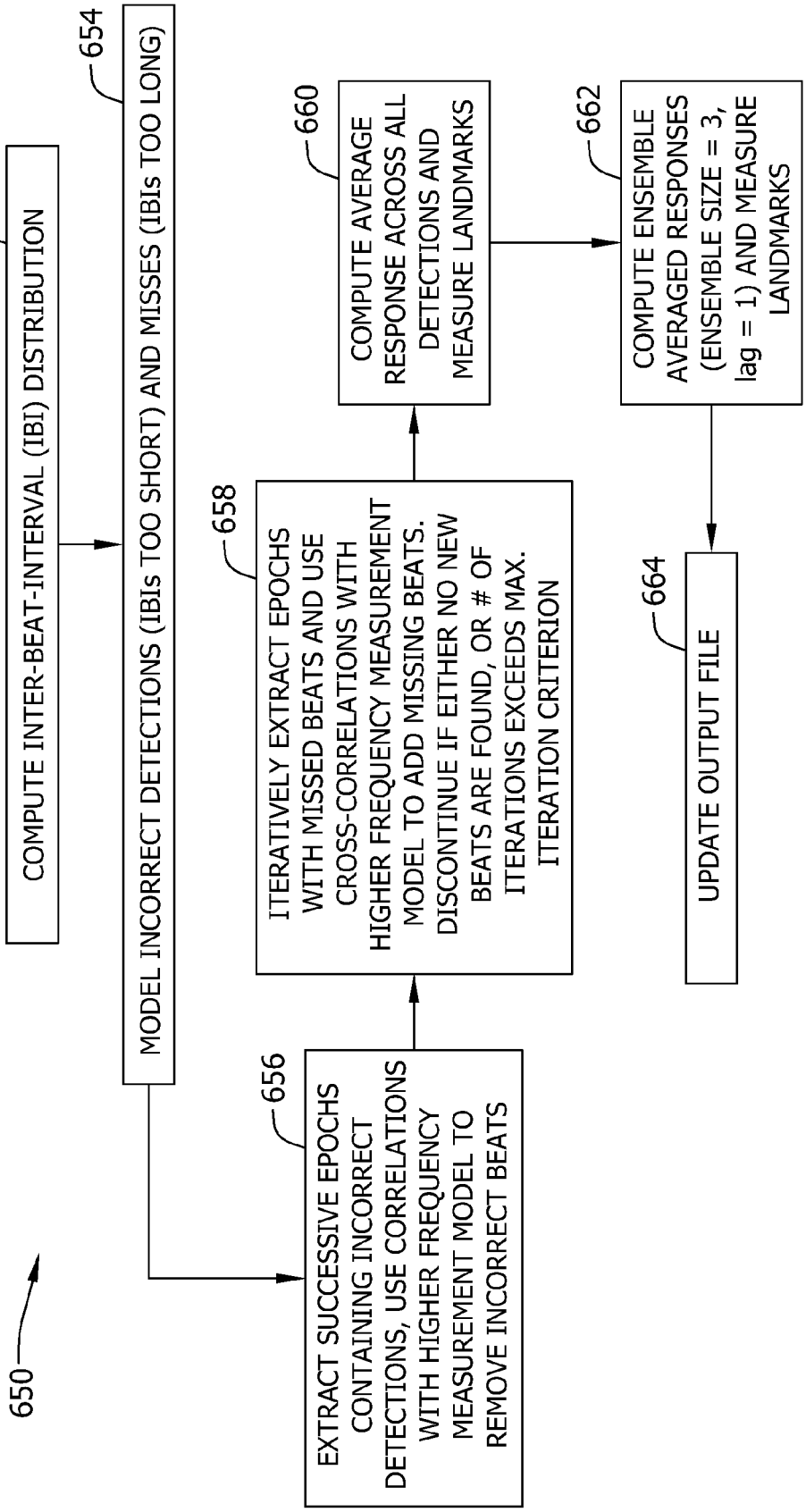

600
602
READ IN 25 sec OF DATA FROM PRE-PROCESSED SIGNAL FILE (3 sec OVERLAP WITH PRECEDING EPOCH)
604
IDENTIFY "CANDIDATE" BEATS USING CROSS-CORRELATION BETWEEN HEART SOUNDS INPUT CHANNEL AND HEART SOUNDS MODEL (BOTH DOWN-SAMPLED TO 20 Hz)
606
IDENTIFY APPROPRIATE MAXIMUM VELOCITY PEAKS AND EXTRACT EPOCHS IF AMPLITUDE OF MAX. VELOCITY PEAK LIES WITHIN EXPECTED VALUES
608
LABEL EXTRACTED EPOCHS AS "DETECTED BEATS" IF CORRELATION WITH MAX. VELOCITY DETECTION MODEL EXCEED CRITERION
610
EXTRACT LOWER AND HIGHER FREQ. LANDMARK DETECTION EPOCHS
612
DETECT AND QUANTIFY SINGLE BEAT LANDMARKS (IN HIGHER AND LOWER FREQUENCY SIGNALS)
614
DYNAMICALLY UPDATE MODELS
616
IDENTIFY EPOCH POINTS EXCEEDING LOW AND HIGH FREQUENCY "NOISE" CRITERIA
618
HAS END OF INPUT FILE BEEN REACHED?
YES
NO
620
WRITE ALL DETECTIONS AND MEASURES TO OUTPUT FILE

FIG. 11


650
652
COMPUTE INTER-BEAT-INTERVAL (IBI) DISTRIBUTION
654
MODEL INCORRECT DETECTIONS (IBIs TOO SHORT) AND MISSES (IBIs TOO LONG)
656
EXTRACT SUCCESSIVE EPOCHS CONTAINING INCORRECT DETECTIONS, USE CORRELATIONS WITH HIGHER FREQUENCY MEASUREMENT MODEL TO REMOVE INCORRECT BEATS
658
ITERATIVELY EXTRACT EPOCHS WITH MISSED BEATS AND USE CROSS-CORRELATIONS WITH HIGHER FREQUENCY MEASUREMENT MODEL TO ADD MISSING BEATS. DISCONTINUE IF EITHER NO NEW BEATS ARE FOUND, OR # OF ITERATIONS EXCEEDS MAX. ITERATION CRITERION
660
COMPUTE AVERAGE RESPONSE ACROSS ALL DETECTIONS AND MEASURE LANDMARKS
662
COMPUTE ENSEMBLE AVERAGED RESPONSES (ENSEMBLE SIZE = 3, lag = 1) AND MEASURE LANDMARKS
664
UPDATE OUTPUT FILE

SYSTEMS AND METHODS FOR NON-CONTACT BIOMETRIC SENSING

BACKGROUND

[0001] The field of the disclosure relates generally to emergency response situations and more specifically, to methods and systems for non-contact biometric sensing.

[0002] In emergency response to disasters of various kinds, first responders are hampered by being unable to reach victims, or are encased in protective equipment that prevents sufficient contact with victims to do standard medical triage. No solution currently exists which permits noncontact standoff measurement of human vital signs. Existing solutions require contact with the victim, for example, palpating the neck or wrist of victim to measure pulse rate or respiration and/or listening for a heart beat with an ear pressed against a chest. As can be seen from the preceding description, existing triage techniques require contact. As a result triage cannot be done when contact is prevented by lack of access or when intervening materials (e.g., biohazards) hamper contact.

BRIEF DESCRIPTION

[0003] In one aspect, a non-contact biometric sensing device is provided. The device includes a processing device, a user interface, a display , a laser doppler vibrometer sensor, and an infrared camera all communicatively coupled to the processing device. The processing device is programmed to utilize mechanical motion data received from the laser doppler vibrometer sensor and thermal distributions data from the infrared camera to calculate biometric data, when signals originating from the laser doppler vibrometer sensor and the infrared camera are reflected back towards the sensing device from a target.

[0004] In another aspect, a method for sensing biometric parameters associated with an object, without contacting the object, is provided. The method includes directing a plurality of visible laser beams, emanating from a sensing device, onto the object to provide an aiming function, causing a signal from a laser doppler vibrometer sensor, the signal emanating from the sensing device, to impinge the object in the vicinity of the visible laser beams, receiving infrared data from the object at an infrared camera associated with the sensing device, the infrared data in the vicinity of the visible laser beams, and utilizing mechanical motion data associated with the object as sensed by the laser doppler vibrometer sensor and thermal distribution data as sensed by the infrared camera to calculate biometric data associated with the object.

[0005] In still another aspect, a non-contact biometric sensing device is provided. The sensing device includes a plurality of ranging lasers each configured to emanate a visible laser beam, oriented such that the visible laser beams converge at a point distant from the sensing device, thereby enabling the laser beams to be operable in aiming the sensing device at a target object. The sensing device further includes a laser doppler vibrometer sensor configured to sense mechanical motion associated with the target object, an infrared camera configured to sense thermal distribution data associated with the target object, and a visible light camera operable to obtain an image of the target object that includes the visible laser beams. The sensing device is programmed to determine a distance to the target object based upon a distance between the visible beams and further operable to use the determined distance to the target to focus the laser doppler vibrometer sensor, the infrared camera, and the visible light camera on the target object.

[0006] The features, functions, and advantages that have been discussed can be achieved independently in various embodiments or may be combined in yet other embodiments further details of which can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a depiction of a person using one embodiment of a remote biometric measuring device to measure vital signs of another person.

[0008] FIG. **2** is a block diagram of a non-contact biometric sensing device.

[0009] FIG. **3** is a top isometric view of the non-contact biometric sensing device of FIG. **2**.

[0010] FIG. **4** is bottom isometric view of the non-contact biometric sensing device of FIG. **2**.

[0011] FIG. **5** is a top isometric view of an assembled non-contact biometric sensing device within a chassis.

[0012] FIG. **6** is a block diagram of a pointing stabilization system.

[0013] FIG. **7** is a flow diagram describing operation of the non-contact biometric sensing device of FIG. **2**.

[0014] FIG. **8** is a flow diagram of a data pre-processing stage for a pulse algorithm.

[0015] FIG. **9** is a flow diagram of a model calibration stage for a pulse algorithm.

[0016] FIG. **10** is a flow diagram of an initial detection/quantification stage for a pulse algorithm.

[0017] FIG. **11** is a flow diagram of a post-detection processing stage for a pulse algorithm.

DETAILED DESCRIPTION

[0018] The described embodiments include a handheld emergency response triage device, for example, to assist in the on-scene assessment of victim status, via standoff assessment of key physiological parameters, the device usable by personnel wearing PPE. In embodiments, the device combine a laser Doppler vibrometry sensor with an infrared imaging device, to measure human biometric signals without contact, and with a standoff distance between the user and the person whose biometric signals are being measured. As further described, other embodiments include other non-contact physiological measuring methods and devices. FIG. **1** depicts such a device in one contemplated use. More specifically, FIG. **1** depicts a first responder **10** to an emergency situation. The circumstances and types of such emergency situations are nearly unlimited, therefore, for purposes of this disclosure, the description utilizes the example of a chemical spill or leak. Embodiments of the described device allow for the evaluation of the physical condition of accident victims remotely, safely, and accurately, minimizing the risk to first responders.

[0019] In such situations, the first responder will generally be wearing some type of personal protection equipment (PPE) that prevents him from physically contacting a person **20** that has been compromised by the emergency situation. The emergency situation may be of a nature where physical contact between the first responder **10** and the person is hazardous to the first responder **10**. To address the triage needs of

person **20**, the first responder **10** is equipped with a non-contact biometric sensing device **50**.

[0020] Non-contact biometric sensing device **50**, in various embodiments, allows the first responder **10** to measure the physiological parameters of person **20**. The measured physiological parameters provide the first responder **10** with indicators of physical condition of person **20**, for example, by measuring mechanical motion with a laser and thermal distributions with an infrared camera. In such embodiments, the laser is able to measure mechanical motion at the surface of the skin of person **20**, due to respiration and heart beat. As shown in FIG. **1**, some embodiments of non-contact biometric sensing device **50** are handheld devices. Other portable configurations are contemplated.

[0021] FIG. **2** is a block diagram of one embodiment of non-contact biometric sensing device **50**. Device **50** combines an infrared camera **52**, a visible camera **54** and a laser doppler vibrometer sensor **60**. In order to operate in a handheld mode, the non-contact biometric sensing device **50** includes a processing device **70** which includes programming that operates to remove the motion of the user (first responder **10**). In order to operate over a number of ranges, the non-contact biometric sensing device **50** includes autofocus methods programmed into the processing device **70** for the optical sensors. In the illustrated embodiment, there is an autofocus device **80** associated with the infrared camera **52**, an autofocus device **82** associated with the visible camera **54**, and an autofocus device **84** associated with the laser doppler vibrometer sensor **60**. In addition to the autofocus device **84**, laser doppler vibrometer sensor **60** includes a waveform generator **100**, a solenoid drive **102**, a tuning fork/solenoid **104**, a laser driver **106**, a laser **108** and associated fiber optics **110**. A two-axis fine steering mirror **112** is included in embodiments of non-contact biometric sensing device **50** to stabilize laser beams emanating from and received by laser doppler vibrometer sensor **60**.

[0022] In alternative embodiments, additional sensors are integrated into non-contact biometric sensing device **50** including ranging lasers **120**, gyroscopes **130**, and a detector amplifier/ADC **140** (analog-to-digital converter). Fine steering mirror **112** may also be utilized to stabilize laser beams emanating from and received by ranging lasers **120**. Ranging lasers **120** provide visible laser guide beams which provide an indication for the user of where the sensors of device **50** are pointed. For example, if the visible laser beams are impinging person **20** (shown in FIG. **1**) the user **10** knows that the other sensors (e.g., visible camera **54**, IR camera **52**, and laser doppler vibrometer sensor **60** are also directed to person **20**. In certain embodiments, gyroscopes **130** are MEMS gyroscopes.

[0023] In embodiments, visible camera **54** is utilized for platform motion detection and processing device **70** (along with an algorithm running thereon) uses the information from visible camera **54** to remove the effects of motion of user **10** from the readings received from the other sensors. Similarly, gyroscope **130** is utilized to remove the hand motion associated with a user **10**. In embodiments, and as described within the following paragraphs, functions included within non-contact biometric sensing device **50** include a linear motion detector, display, control buttons, an embedded computer, a field programmable gate array and associated firmware implementation of motion estimation algorithms, mirror controls, and sensor interfaces.

[0024] Non-contact biometric sensing device **50** further includes a battery/power subsystem **150**, a user interface **160** and a user display **170**. The battery/power subsystem **150** provides power to the other components of the device **50**. The user interface **160** is communicatively coupled to the processing device **70** such that the programming stored therein can react to user input. The user display **170** is communicatively coupled to the processing device **70** such that information from the sensors described herein may be presented to the first responder **10**.

[0025] As further described herein, device **50** enables standoff use, and also allows use by personnel wearing personal protective equipment, which hampers triage by direct contact methods. Device **50** measures mechanical motion, and measures temperature distribution, without contact at ranges of about five feet to about forty feet. Signals from the various sensors are processed by the processing device **70** to extract pulse rate, measure a breathing rate, and generate a map of temperature distribution on the human skin. These measurements indicate physical condition as calibrated with the measurements of physical condition by other contact methods such as strain belts, EKG and temperature probes.

[0026] Turning now to FIG. **3**, a top isometric view of non-contact biometric sensing device **50** is provided. Components that were described with respect to FIG. **2** are shown in FIG. **3** using the same reference numerals. Additionally, FIG. **3** illustrates two visible laser drivers **200** and **202** that are associated with the ranging lasers **120**. An optical splitter **210** allows the wavelength of light associated with the laser doppler vibrometer sensor **60**, from auto focus **84** to pass through to fine steering mirror **112**. In the illustrated embodiment, the lenses **220** and **222** associated with autofocus devices **80** (not shown in FIGS. **3**), **82**, and **84** respectively include a linear translator **224**, **226** which moves the respective lens **220**, **222** to accomplish the focusing function.

[0027] FIG. **4** is a bottom isometric view of non-contact biometric sensing device **50** which illustrates the above described IR camera **52**, battery/power subsystem **150** and printed circuit boards **250** which house the processing device **70** (not shown in FIG. **4** as well as supporting circuits for user interface **160** and display **170**. In embodiments, an autofocus function is added to the IR camera **52**, as shown in FIG. **2**. For clarity, the autofocus function is not shown in FIG. **4** though in practice such a function is similar to **82** and **84** shown in FIG. **3** and in embodiments utilizes a linear translator.

[0028] FIG. **5** is a top isometric view of an assembled non-contact biometric sensing device **50** which includes a chassis **300** further including a plurality of shock and vibration isolating bumpers **310** mounted on corners of chassis **300**. Also shown in FIG. **5** are the display **170** and buttons **320** and **322** on handles **330** and **332** of chassis. Buttons **320** and **322** make up at least a portion of user interface **160**. Windows **340** and **342** for the ranging lasers **120** are shown as well as windows **350** and **360** for the infrared camera **52** and the visible camera **54**.

[0029] As mentioned above, the above described system is operable for standoff measurement of biometric signals and is contemplated to function, at least in part, as a standoff triage device for civilian first responders and military first responders. To provide such functionality, the visible light from the ranging lasers **120** is utilized by the visible camera **54** to provide data that can be utilized by the processing device **70** to calculate an auto focus value for operation of the infrared camera **52** and the laser doppler vibrometer sensor **60**. Spe-

cifically, the visible camera **54** sees the two laser beams from ranging lasers **120**, measures how far apart the beams are at an impact point (e.g., on person **20** (shown in FIG. **1**). The distance between the beams at the impact is utilized by the processing device **70** to determine a distance to the impact point and therefore control the autofocus function associated with the infrared camera **52**, the visible camera **54**, and the laser doppler vibrometer sensor **60**.

[0030] In regard to operation of the laser doppler vibrometer sensor **60**, it operates through the detection of reflected signals as sensed by detector/amplifier/ADC **140**. which passes the detected signals onto the processing device **70** which is programmed to convert the received signals into velocities which is then passed to a triage algorithm. In embodiments, the laser doppler vibrometer sensor **60** has a data rate of about 800 Hz, a frequency resolution of 16 bits (−1 Hz in 100 kHz), a signal to noise resolution of 14 bits (10 in 10^6), a mirror size of about one inch in diameter, a mirror quality of lambda/4, and is gold coated. The focus stage resolution of the laser doppler vibrometer sensor **60**, in one embodiment, is 3.4 microns in 3 mm (0.2 Rayleigh range) and the ranging resolution is 0.04 in at 5 ft and two inches at 40 ft (0.1 Rayleigh range).

[0031] As is understood by those skilled in the art, non-contact biometric sensing device **50** is programmed with several operating modes, which are activated via the user interface **160** and executed by the processing device **70**, which either accesses or includes a memory for storing the instructions utilized in operation of non-contact biometric sensing device **50**. In embodiments, a sleep mode is included which operates to conserve battery power by turning the display **170** off, turning the various lasers off, and putting the processing device **70** into a low power mode. In a search mode, the display **170** is on, the lasers are on, a display of the long-wavelength infrared (LWIR) image provided by IR camera **52** is provided on display **170**, and the beam stabilization afforded by the gyroscopes **130** and visible camera **54** for the laser doppler vibrometer sensor **60** is inactive and fixed in a neutral position.

[0032] Beam stability for one embodiment of the laser doppler vibrometer sensor **60** is about one centimeter. At 40 feet, this stability translates to about 0.047 degrees or about 820 micro radians. User hand jitter is stabilized up to about 20 Hz which implies a control loop bandwidth of about 2×, or 40 Hz, and a controller update rate of 10×, or 400 Hz. Beam pointing accuracy of the laser doppler vibrometer sensor 60 is about 1 to 1.5 centimeters.

[0033] FIG. **6** is a block diagram **400** of a pointing stabilization system and algorithm for device **50**. Gyroscopes **130** provide sensing of two-axis angular rates that are associated with the user handling of the device **50**. Rate filters **402** and integrator **404** within processing device **70** convert sensed rates to estimates of high-frequency platform angular pointing errors. In parallel, a sensed image **406** from visible camera **54** and a stored reference image **408** are subjected to an image sensor processing algorithm **410** to determine pointing errors due to low-frequency angular platform motion and two-DOF (depth of field) platform translations. A position control algorithm **412** determines steering mirror angles to compensate, and cancel out, such motion. Outputs of the rate filtering **402** and integrator **404** algorithms are combined with the outputs of the position control algorithm **412** and provided as data to the steering mirror control function **420** which continually adjusts positioning of the mirror **430** associated with laser doppler vibrometer sensor **60** to provide a stabilized laser beam. The gyroscopes **130** sense and outputs therefrom are utilized to cancel-out higher-frequency platform rotations. Concurrently, the camera-based motion-estimation algorithm compensates for DC-to-mid-frequency platform rotation and platform translation. The unstabilized guide beams from ranging lasers **120** aid the operator in keeping the steering mirror within range limits.

[0034] To further describe operation of non-contact biometric sensing device **50**, FIG. **7** is a flow diagram **450** describing operation of the non-contact biometric sensing device **50** for the sensing of biometric parameters associated with an object. Initially, the user directs **452** a plurality of visible laser beams, emanating from sensing device **50**, onto the object to provide an aiming function. Through user input or programming, a signal is caused **454** to be output from the laser doppler vibrometer sensor **60**. The signal emanating from the laser doppler vibrometer sensor **60** from sensing device **50** thus impinges the object in the vicinity of the visible laser beams. Infrared data is received **456** from the object at the infrared camera **52** associated with the sensing device **50**, where the infrared data is also in the vicinity of the visible laser beams. Mechanical motion data associated with the object as sensed by the laser doppler vibrometer sensor and thermal distribution data as sensed by the infrared camera is utilized **458** to calculate biometric data associated with the object.

[0035] In use, the user **10** aims the device **50** at person **20** using the guide beams from the visible ranging lasers **120**, which are the dual, un-stabilized guide beams, and the measurement location for the infrared camera **54** and the laser doppler vibrometer sensor **60** is centered between guide beams. In one embodiment, the user **10** presses a "lock" button when guide beams are in the vicinity of the desired measurement location. An initial lock location could be several inches away from desired location, and the user **10** may utilize fine-adjust controls to move lock-location from initial to desired location. Alternatively, the user **10** presses a lock button repeatedly until initial lock is close enough to the desired measurement location. The user **10** holds the unstabilized guide beams in the vicinity of the area being measured during measurement for a period of time due to limited range on the fast steering mirror **112**.

[0036] In an autofocus mode, a range to the target is measured, based on the beams provided by the visible ranging lasers **120**, focus is set, beam stabilization for the laser doppler vibrometer sensor **60** is active, and a final LWIR image is acquired. In addition, a patient identifier is incremented. In a first acquire mode, the signal from laser doppler vibrometer sensor **60** is acquired and displayed, acquisition of the signal is the first attempt to detect a pulse or other signs of life of person **20**. In a second acquire mode, acquisition and display of the laser doppler vibrometer sensor **60** signal is continued, and an attempt to detect respiration as well as the processing and display of a pulse rate is begun. In a third acquire mode, acquisition and display of the laser doppler vibrometer sensor **60** signal is continued, and an attempt to process and display respiration rate is made. In an analyze mode, beam stabilization for the laser doppler vibrometer sensor **60** signal is inactive, while the processing device continues to analyze collected data to present a diagnosis. A diagnostic mode is used to capture and store raw data for troubleshooting. One or more of the buttons **320** and **322** are used as an on/off switch and as a switch to change between the above described operations

modes or to select a body part which is being analyzed (e.g., carotid, chest, other). In embodiments, LEDs may be incorporated to provide an indication of which mode the device **50** is operating in.

[0037] As described herein, the device **50** is utilized to perform a triage function, typically to be used by first responders at the scene of an incident or accident. The triage function can be broken down to establish a timeline hierarchy of analysis. Specifically, the first **3-5** seconds is utilized to detect primitive signs of life, including, displaying of mechanical motion against time, displaying the image as provided by IR camera **52** as a colorized map of absolute temperature, and detecting a pulse, as well as including an indication of confidence and/or signal quality. At 10-20 seconds, respiration mechanical motion is detected while the pulse rate is processed and displayed, including an indication of confidence and/or signal quality. At 30-60 seconds respiration rate is processed and displayed, pulse quality is evaluated, and if possible, a diagnosis is presented and/or a quantitative measure of patient health (i.e. 0=dead . . . 100=healthy) is provided, also including an indication of confidence and/or signal quality.

[0038] FIG. **7** is a flow diagram **500** of a data pre-processing stage for a pulse algorithm. A velocity signal is read **502** by the laser doppler vibrometer sensor **60** which is sampled **504** by the processing device **70**, through detector/amplifier **140**, and despeckled to create **506** new output channels including a heart sound channel **510**, a maximum velocity peak detection channel **512**, a landmark detection/measurement channel **514**, an artifact auto-detection channel **516** and a respiration channel **518**. These channels are passed through various filters and other processing and the results are written **520** to a file.

[0039] FIG. **8** is a flow diagram **550** of a model calibration stage for a pulse algorithm. In one embodiment, 15 seconds of data from a pre-processed file (see FIG. **7**) is read **552** and maximum likelihood heartbeats are identified **554** using, for example, generic models from which individualized models are created **556**. The models include, in one embodiment, a heart sounds model **560**, a maximum velocity peak detection model **562**, a landmark detection/measurement model **564**, and an artifact auto-detection model **566**. In regard to the landmark detection/measurement model **564**, if the correlation between a current higher frequency measurement model and the model from the previous 15 second input exceeds **570** a criterion, consecutive models are averaged **572** and stored. If the criterion is not exceeded **570**, another 15 seconds of data is read **552** and the process continues.

[0040] FIG. **9** is a flow diagram **600** of an initial detection/quantification stage for a pulse algorithm. Initially, **25** seconds of data is read **602** in from a pre-processed signal file (see FIG. **7**), in one embodiment, with a three second overlap with the preceding epoch. "Candidate" beats are identified **604** using cross-correlation between heart sounds input channel and heart sounds model, for example, when both are down-sampled to 20 Hz. Appropriate maximum velocity peaks and extract epochs are identified **606** if an amplitude of a maximum velocity peak lies within expected values. Next, extracted epochs are labeled **608** as "detected beats" if correlation with the maximum velocity detection model exceeds a criterion. Lower and higher frequency landmark detection epochs are extracted **610** and single beat landmarks (in higher and lower frequency signals) are detected **612** and quantified. Models are dynamically updated **614**, and epoch points exceeding low and high frequency "noise" criteria are identified **616**. If the end of the input file been reached **618**, write **620** all detections and measurements to and output file. Otherwise read **602** another 25 seconds of data.

[0041] FIG. **10** is a flow diagram **650** of a post-detection processing stage for a pulse algorithm. Initially, an Inter-Beat-Interval (IBI) distribution is computed **652** and incorrect detections (IBIs too short) and misses (IBIs too long) are modeled **654**. Successive epochs containing incorrect detections are extracted **656**, and correlations with higher frequency measurement model are used to remove incorrect beats. Epochs with missed beats are iteratively extracted **658** and cross-correlations with higher frequency measurement models are used to add missing beats. Discontinue if either no new beats are found, or if the number of iterations exceeds a maximum iteration criterion. An average response across all detections and measure landmarks is computed **660** and ensemble averaged responses (ensemble size=3, lag=1) are computed **662**. Landmarks are measured and an output file is updated **664**.

[0042] The description of the different advantageous embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different advantageous embodiments may provide different advantages as compared to other advantageous embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

[0043] This written description uses examples to disclose various embodiments, which include the best mode, to enable any person skilled in the art to practice those embodiments, including making and using any devices or systems and performing any incorporated methods. The patentable scope is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

1. A non-contact biometric sensing device comprising:
a processing device,
a user interface communicatively coupled to said processing device;
a display communicatively coupled to said processing device;
a laser doppler vibrometer sensor communicatively coupled to said processing device; and
an infrared camera communicatively coupled to said passing device, said processing device programmed to utilize mechanical motion data received from said laser doppler vibrometer sensor and thermal distributions data from said infrared camera to calculate biometric data, when signals originating from said laser doppler vibrometer sensor and said infrared camera are reflected back towards said device from a target.

2. The non-contact biometric sensing device according to claim **1** further comprising a plurality of ranging lasers each

configured to emanate a visible beam for use as an aiming device for said sensing device.

3. The non-contact biometric sensing device according to claim **2** wherein signals from said laser doppler vibrometer sensor and said infrared camera are configured to emanate from a position between the visible beams of said ranging lasers.

4. The non-contact biometric sensing device according to **2** further comprising a visible camera communicatively coupled to said processing device, said processing device programmed to utilize data received from said visible camera, including the tracking of beams from said ranging lasers, to remove the hand motion associated with a user of said sensing device from the data received from said laser doppler vibrometer sensor and said infrared camera.

5. The non-contact biometric sensing device according to claim **4** wherein said processing device is programmed to determine a change in the X and Y directions between an image sensed by said visible camera and a stored reference image previously sensed by said visible camera, said processing device further programmed to continually adjust positioning of mirrors associated with said laser doppler vibrometer sensor, based on the changes in the X and Y directions, to provide a stabilized laser beam from said laser doppler vibrometer sensor.

6. The non-contact biometric sensing device according to claim **1** further comprising at least one gyroscope communicatively coupled to said processing device, said processing device programmed to utilize data received from said gyroscopes to remove the hand motion associated with a user of said sensing device from the data received from said laser doppler vibrometer sensor and said infrared camera.

7. The non-contact biometric sensing device according to claim **6** wherein said gyroscopes are configured to output a pitch rate and a yaw rate that is associated with user handling of said sensing dome, said processing device programmed with an algorithm which uses sensed angular rate data to estimate higher-frequency angular pointing errors and said processing device is programmed to continually adjust positioning of mirrors associated with said laser doppler vibrometer sensor, to remove the hand motion associated with a user of said sensing device.

8. The non-contact biometric sensing device according to claim **2** further comprising a visible camera communicatively coupled to said processing device, and a gyroscope communicatively coupled to said processing device, said processing device programmed to utilize data from said gyroscope to cancel out higher frequency platform rotations sensed by said gyroscope, said processing device programmed to utilize data from said visible camera to compensate for lower frequency rotations and X/Y translations.

9. The non-contact biometric sensing device according to claim **2** wherein said processing device is programmed to utilize a distance, at a target location, between the laser beams emanating from said ranging lasers and sensed by said visible camera to determine a rang to the target.

10. The non contact biometric sensing device according to claim **1** further comprising:

a plurality of ranging lasers each configured to emanate a visible beam for use as an aiming device for said sensing device; and

a visible camera communicatively coupled to said processing device said laser doppler vibrometer sensor, said infrared camera, and said visible camera comprising lenses associated with an auto focus function, said processing device programmed with the autofocus function, the autofocus function based on a range to a target as measured using the visible beams from said ranging lasers.

11. (canceled)

19. A non-contact biometric sensing device comprising:

a plurality of ranging lasers each configured to emanate a visible laser beam, the ranging lasers oriented such that the visible laser beams converge at a point distant from said sensing device, the laser beams operable in aiming said sensing device at a target object;

a laser doppler vibrometer sensor configured to sense mechanical motion associated with the target object;

an infrared camera configured to sense thermal distribution data associated with the target object; and

a visible light camera operable to obtain an image of the target object that includes the visible laser beams, said sensing device programmed to determine a distance to the target object based upon a distance between the visible beams and farther operable to use the determined distance to the target to focus said laser doppler vibrometer sensor, said infrared camera and said visible light camera on the target object.

20. The non-contact biometric sensing device according to claim **19** further comprising a gyroscope, said sensing device programmed to utilize data from said gyroscope and image data from said visible light camera remove effects of movement of said sensing device from data associated with said laser doppler vibrometer sensor and said infrared camera

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